NASA-CR-54776
BRLD NO. 3133
COPY NO. 34



# FABRICATION AND TEST OF A FLUERIC POSITION SERVO

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CONTRACT NAS 3-6201



By

THE BENDIX CORPORATION
RESEARCH LABORATORIES DIVISION
Southfield, Michigan

Requests for copies of this report should be referred to:

National Aeronautics and Space Administration
Office of Scientific and Technical Information
Attention: AFSS-A
Washington, D.C. 20546

NASA-CR-54776
BRLD NO. 3133

# Quarterly Report

# FABRICATION AND TEST OF A FLUERIC POSITION SERVO

Approved by: M. H. Cardon
M. H. Cardon, Project Engineer
Machine and Propulsion Controls Department
Energy Conversion and Dynamic Controls Laboratory

Approved by: L. B. Taplin
L. B. Taplin, Manager
Energy Conversion and Dynamic Controls Laboratory
Technical Director, Fluid State Programs

**Prepared for**

**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**

**10 June 1965 to 10 September 1965**

**CONTRACT NAS 3-6201**

Technical Management
NASA Lewis Research Center
Cleveland, Ohio
Advanced Development and Evaluation Division
Dr. William Griffin

By

The Bendix Corporation
Research Laboratories Division
Southfield, Michigan

TABLE OF CONTENTS

## LIST OF ILLUSTRATIONS

FABRICATION AND TEST
OF A FLUERIC POSITION SERVO

Prepared under the direction of:

M. H. Cardon

Approved by:

L. B. Taplin

## ABSTRACT

This report is the first quarterly report of Task-2 of an effort to develop a pneumatic control drum actuator for a nuclear rocket engine in which the electronics have been replaced by flueric devices. The objective of the Task-2 effort is to fabricate and test the system designed and studied in Task-1. In this quarter engineering specification were published, a layout drawing defining the mechanical configuration of flueric circuit was completed, and a breadboard vortex amplifier was designed and built.

# SECTION 1

# INTRODUCTION

This report is the first quarterly report of Task 2 of a two-task effort to develop a pneumatic actuation system in which the electronics which formerly provided the error detection, frequency compensation, and amplification have been replaced with flueric devices.

In Task 1 an all-pneumatic servo actuator with performance characteristics comparable to an existing electropneumatic system was designed and analytically studied. The existing electropneumatic actuation system selected for a base in the study is used to position control drums in a nuclear rocket engine. The results of Task 1 are presented in a Summary Report dated August 31, 1965. The objective of Task 2 of the effort is to fabricate the system designed in Task 1 and to evaluate it experimentally.

In the first quarter of Task 2, detailed circuit and component specifications were published and a preliminary layout defining the mechanical configuration or packaging concept of the flueric circuit was completed. Also, a breadboard, lower stage, vortex valve was designed and fabricated.

In this report, drawings showing the mechanical configuration of the flueric circuit and the breadboard vortex element are presented and discussed. A brief description of the actuation system designed in Task 1 is also included.

## SECTION 2

## SUMMARY

In the first quarter of Task 2, engineering specifications for the actuation system, power control valve and flueric circuits were published. Also, the flueric circuit's mechanical configuration was defined, a breadboard vortex valve for the lower stage flueric circuit and breadboard test fixtures were designed and built, and a method of breadboarding the flueric circuits was established.

The mechanical configuration of the flueric circuit was simplified over that presented in the Task 1 Summary Report. In the present design, a base plate mounted to the AG-20 actuator-motor serves to locate components relative to the actuator-motor and as a manifold and mounting plate. The design selected for the vortex elements allows them to be easily mounted, manifolded, and removed.

The design of the breadboard vortex elements follows the concept selected for the final circuit design.

In the next quarter, the design of the mechanical components will be completed and fabrication will be started. Also, the remaining breadboard flueric devices will be designed and built and circuit tests will be started.

## SECTION 3

## DESCRIPTION OF ACTUATION SYSTEM

In this section the actuation system in which the electronics have been replaced with flueric devices will be described. Included is a description of the load, actuator-motor, power control valve, and flueric circuit.

The actuation system includes rate feedback and frequency varient load pressure feedback, in addition to position feedback.

As is specified, an AG-20 actuator-motor is used. A photograph of this actuator-motor is shown in Figure 3-1. A pictorial schematic of the actuator-motor, the specified load, and the power control valve design selected in the Task 1 study are shown in Figure 3-2.

The actuator load consists of a control drum, its associated friction, and a scram spring. The actuator-motor has two separate pistons mounted on opposite ends of a short rack. The rack drives a pinion gear which is coupled directly to the load.

The power control valve is of the flapper-nozzle type and it incorporates frequency varient negative load pressure feedback. The flapper of the valve is actuated by a pressure differential existing between opposing bellows on the flapper.

A schematic of the actuation system is shown in Figure 3-3. In this system, flueric devices and passive components implement the position-error detection, amplification, and compensation; the rate signal differentiation and amplification; and the summing. The flueric devices used are the vortex valve and pressure amplifier.

A position error signal is generated using an area balancing technique. An electrical position input signal to the torque motor of the position error detector activates a flapper between the nozzles, varying their effective orifice area. These nozzles are coupled to equivalent nozzles in the position feedback transducers. The effective orifice areas of the nozzles in the position feedback transducer are varied by a flapper which is actuated by a cam coupled to the actuator's output shaft. Where the effective orifice area of one set of nozzles

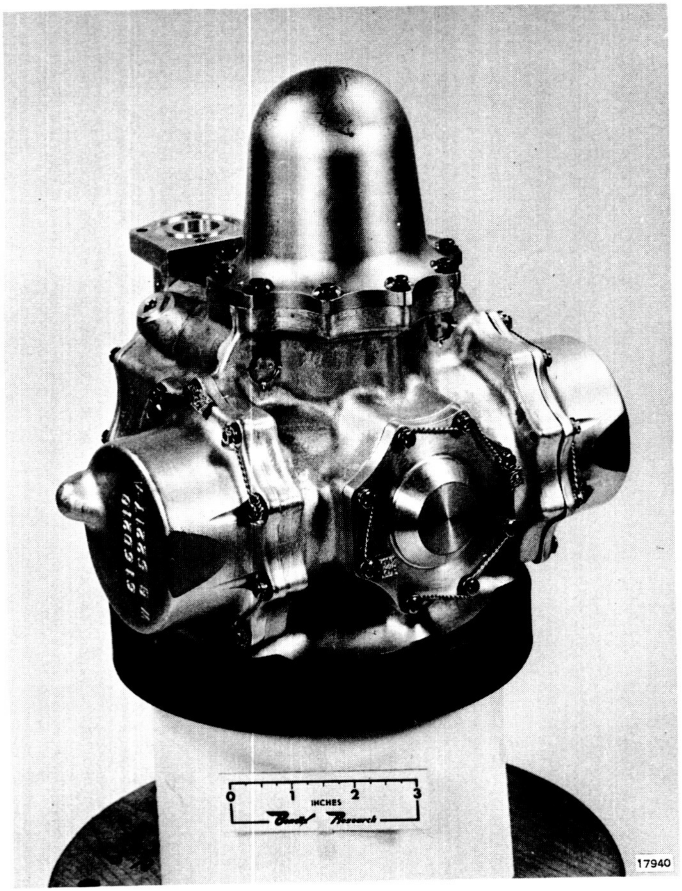


Figure 3-1 - AG-20 Actuator-Motor

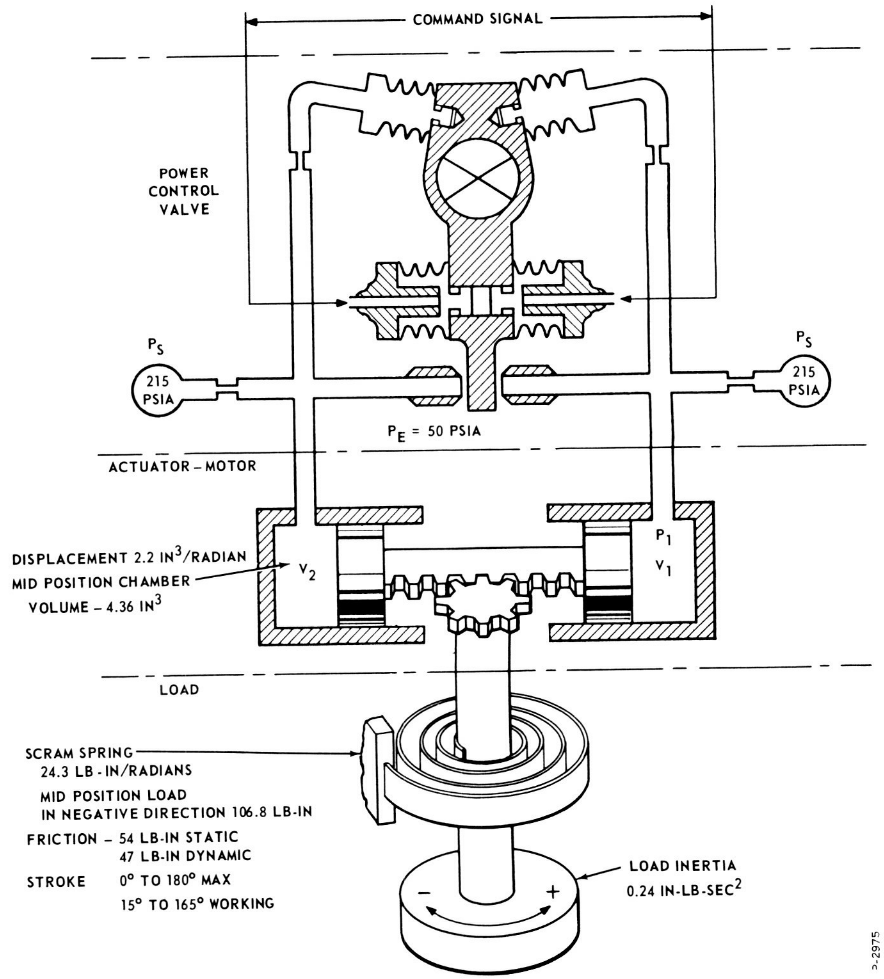


Figure 3-2 - Schematic of Valve, Actuator Motor, and Load

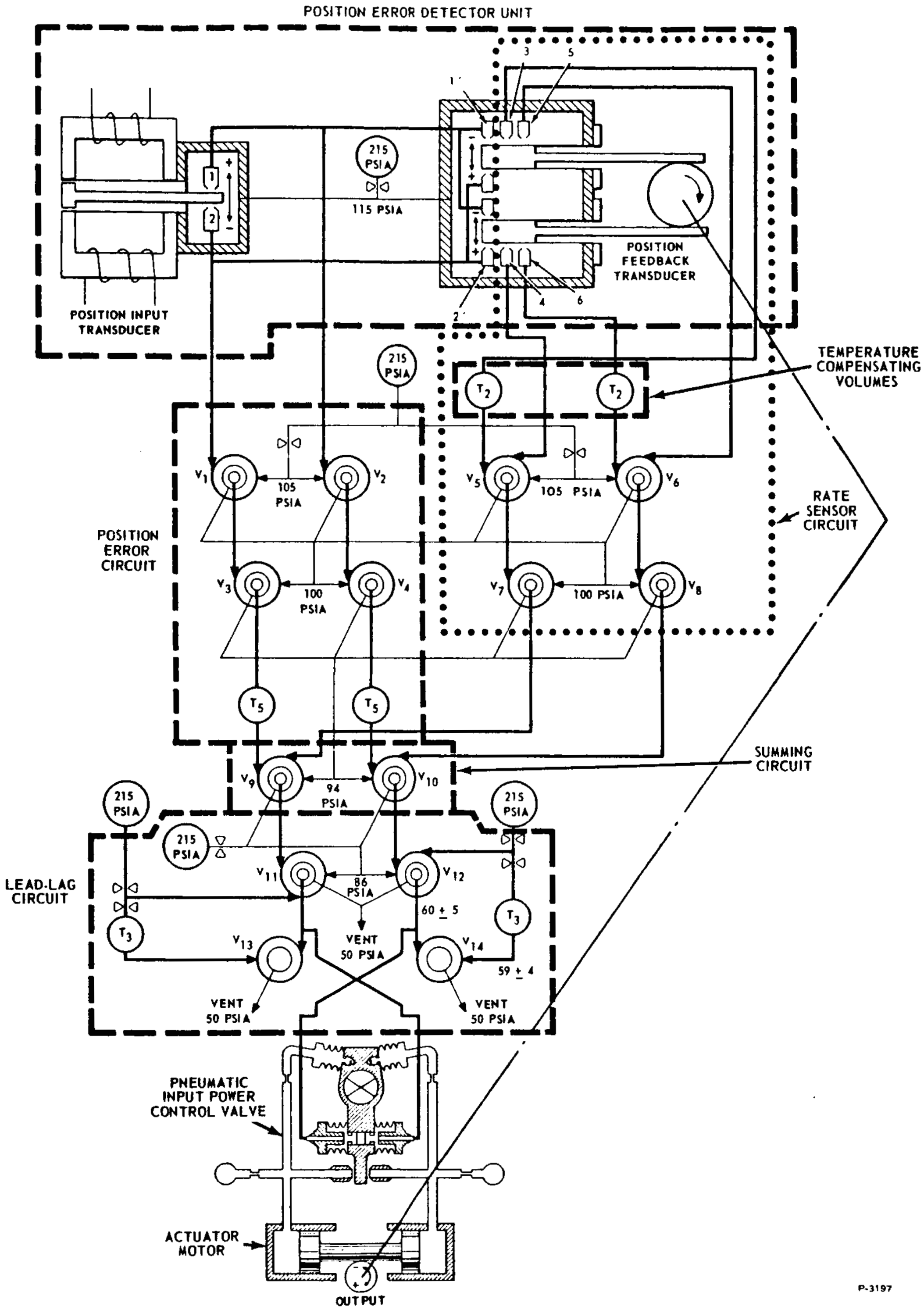


Figure 3-3 - Schematic of Actuator System differs from that of the other, a pneumatic error signal is generated. The error signal is amplified, lagged, and then summed with a rate signal. The rate signal is generated by a pseudo differentiation of a position signal and amplified. The differentiation is performed using a volume-orifice network. In a lead-lag circuit, the signal from the summer is operated on and directed to the input bellows of the power control valve. When the rate signal exceeds a specified value, it overrides the position signal and the system becomes a rate servo, limiting velocity of the actuator.

## SECTION 4

## MECHANICAL DESIGN

In this quarter, engineering specifications were published for the actuation system, position error detector unit, rate sensor circuit, lead-lag circuit, temperature compensating volumes, summing circuit, and power control valve. These components are identified in Figure 3-3.

Also, the mechanical configuration, or packaging, of the flueric circuit was defined. A description of the mechanical configuration follows.

### Mechanical Configuration of the Flueric Circuit

A preliminary layout illustrating the mechanical configuration of the flueric circuit is shown in Figure 4-1. The configuration illustrated has been simplified from that presented in the Task 1 Summary Report, and the dynamic seal on the position feedback transducer's drive shaft has been eliminated.

In the design in Figure 4-1, a base plate is mounted to the AG-20 actuator in place of the potentiometer cover used in the electropneumatic system. The error detector unit, vortex elements, and lag tanks of the flueric circuit are mounted to the base plate. The supply and exhaust flows of the circuit, as well as the input signal to the power control valve, are manifolded through the base plate. The circuit is partially manifolded in the base plate also. The base plate, in addition, locates the error detector unit in relation to the actuator output shaft.

The shaft seal was eliminated by utilizing the sealing capabilities of the position feedback transducer's spring tube to isolate the 650 psia cooling gas from the flueric circuit supply gas. A static seal in the potentiometer cover isolates the cooling gas from the 50 psia ambient pressure inside the package.

The potentiometer shown in Figure 4-1 is for instrumentation purposes and is not required as part of the flueric circuit. This potentiometer can eventually be eliminated, allowing some reduction

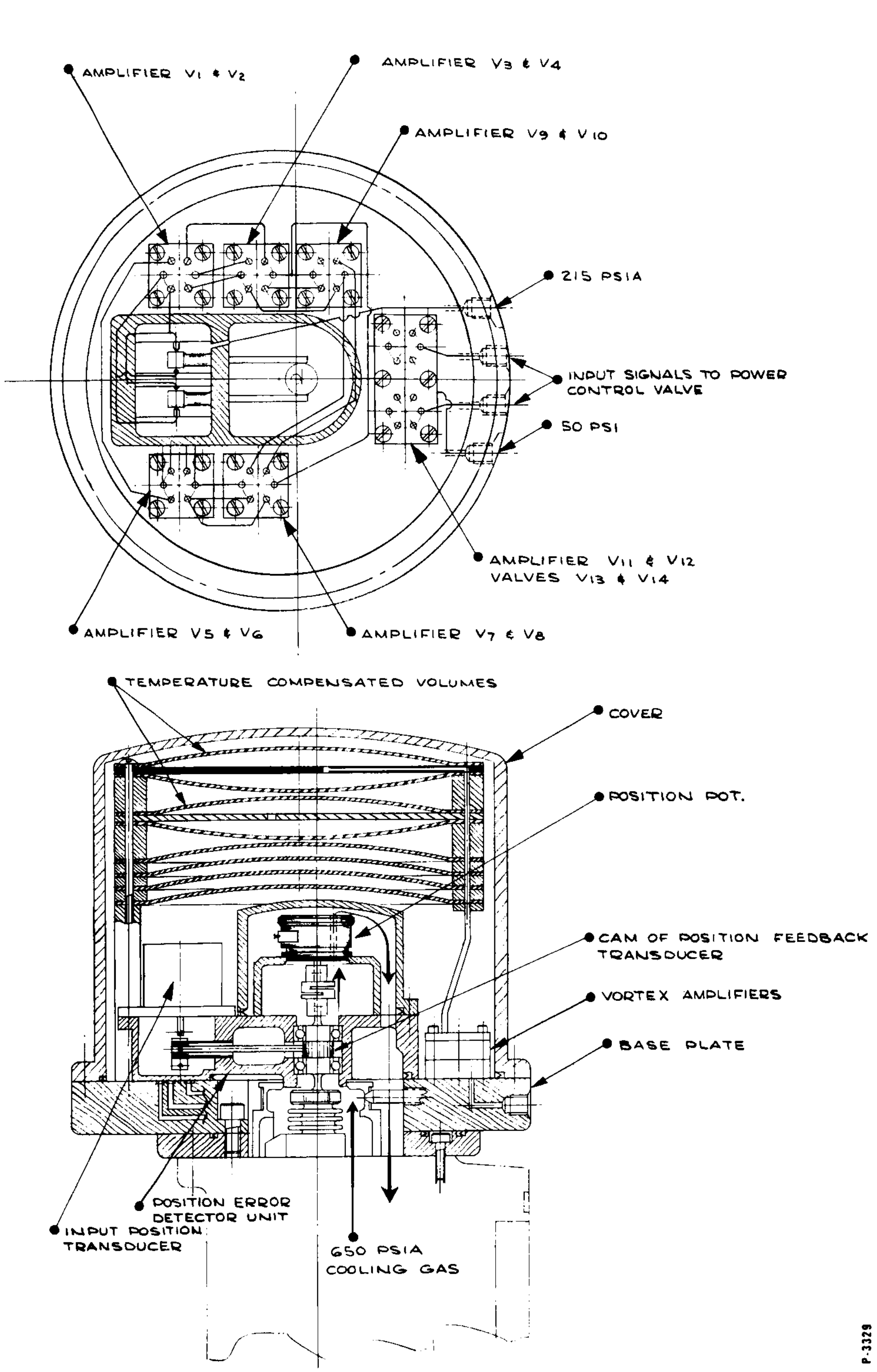


Figure 4-1 - Mechanical Configuration of Flueric Circuit in the height of the flueric circuit package. It is included in this design because it will be useful in evaluating the actuation system when it is initially installed on a reactor.

The tanks, or volumes, used to generate lags in circuit are mounted above the vortex amplifiers and error detector unit. The design of the temperature-compensated volumes is changed from that shown in the Summary Report, to simplify construction. The rim, made of a material with a low coefficient of expansion, has been replaced by a plate which is sandwiched between and welded to the spherical elements made of the high coefficient of expansion material.

Figure 4-2 illustrates the vortex amplifier design and the concept selected for mounting the amplifiers and manifolding communicating passages. The vortex amplifiers will be circular and wafer shaped in design. Supply, exhaust, output, and control signal ports will all be located on a common base circle. It will be possible for these ports to open on either side of the amplifier.

This feature allows the amplifier in series in the circuit to be stacked one on top of the other, without using an intermediate manifold plate. It also allows the amplifiers to be communicated through manifolding in the base plate or tubing manifolded through a plate mounted on top of the amplifier. The single or stacked amplifiers are held to the base plate using through bolts, which makes the removal of a single element for checkout or replacement a simple matter.

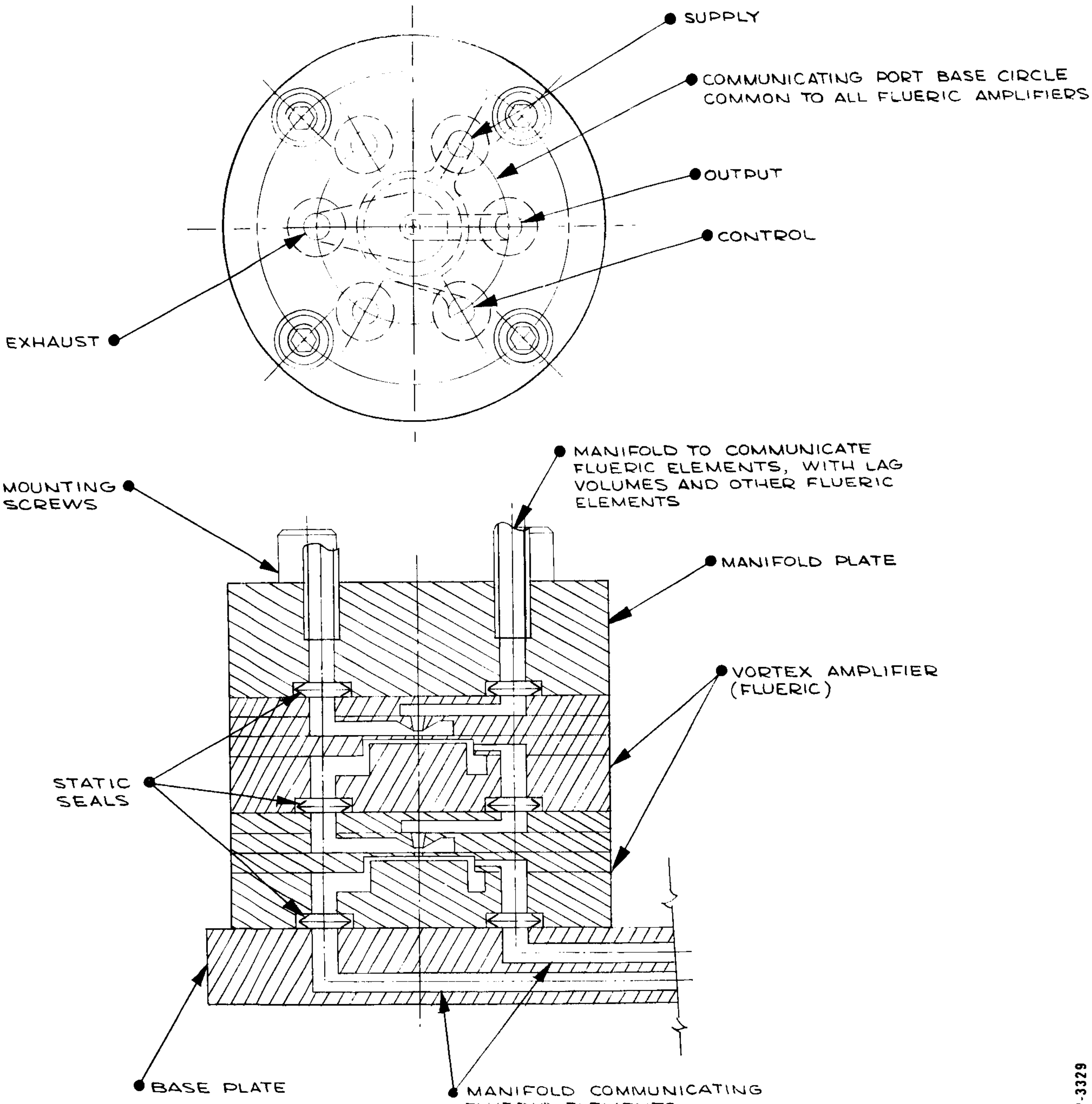


Figure 4-2 - Vortex Amplifier Packaging Concept

## SECTION 5

## BREADBOARD FLUERIC CIRCUIT

In this quarter, breadboard vortex valves for $V_{13}$ and $V_{14}$ of the lead-lag circuit in Figure 3-3 were designed and built. A method of manifolding the vortex amplifiers and valves into breadboard circuits was established, and the test fixture to implement building these circuits was designed and a number of them were built. In this section, the design of the breadboard valves and the method of breadboarding circuits will be discussed.

### 5.1 BREADBOARD VORTEX VALVES

The assembly drawing of the breadboard vortex valve is shown in Figure 5-1. A photograph of the valve on a test fixture and the component parts before assembly is shown in Figure 5-2.

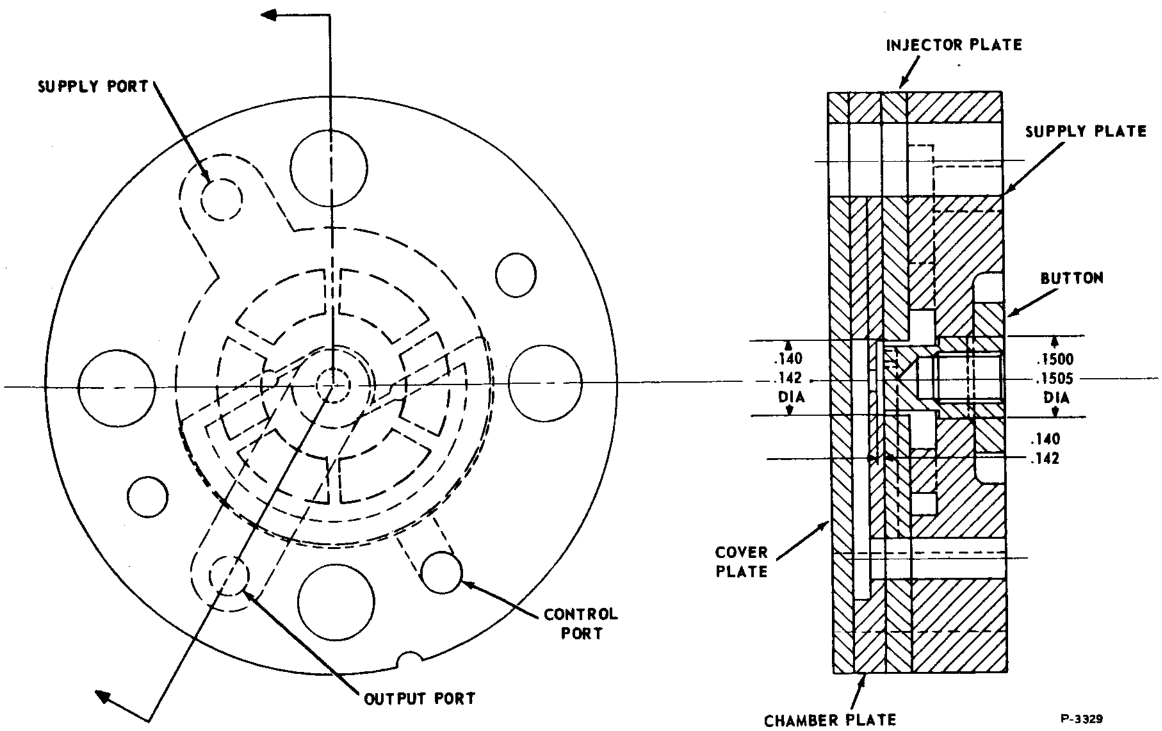


Figure 5-1 - Assembly Drawing of Breadboard Vortex Amplifier

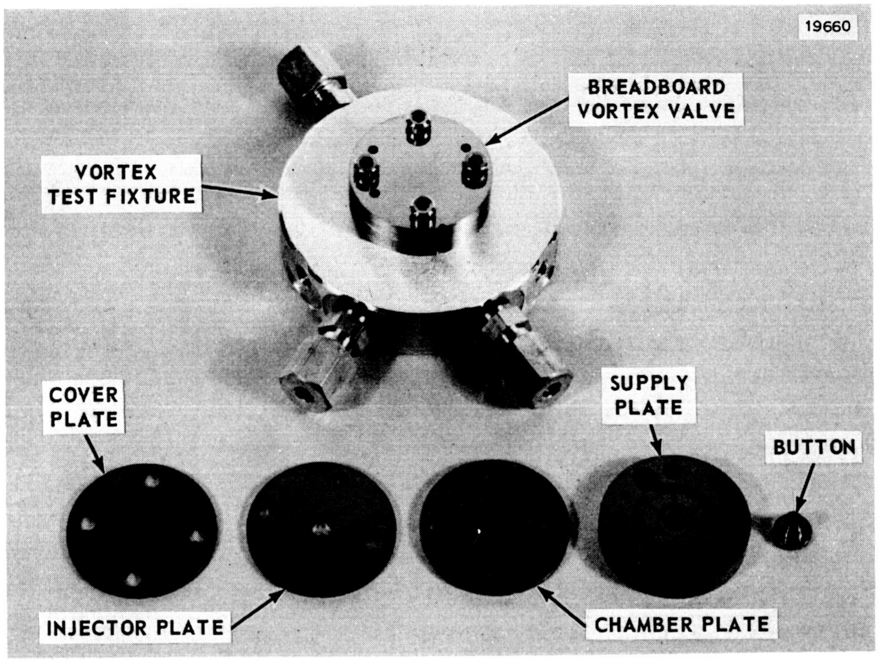


Figure 5-2 - Breadboard Vortex Valve and Test Fixture

The vortex valve has chamber diameter of 0.140 in. and an exit diameter of 0.029 in., resulting in a chamber-diameter-to-exit-diameter ratio of five to one. The chamber length is 0.014 in. and the button diameter is 0.120 in. There are two communicated control ports which are slots 0.010 in. wide by 0.030 in. deep.

The design of the breadboard valve follows the concept established for the final design. The supply exhaust, output, and control ports are all on a common base circle and are on one side of the valve amplifier. Through bolts are used to mount the valve on test fixtures, and an intermediate seal plate is used between the fixture and vortex valve. The seal cavities are designed to accept minature metallic Apex seals (Servotronics Inc.) or semi-standard rubber O-rings.

The valve is made up of four plates and a button (see Figure 5-2). The plates are machined to form the vortex chamber and communicating passages when assembled. In assembly, the plates are bonded together using the copper diffusion process. The button is inserted with a light press-fit after the bonding process is completed.

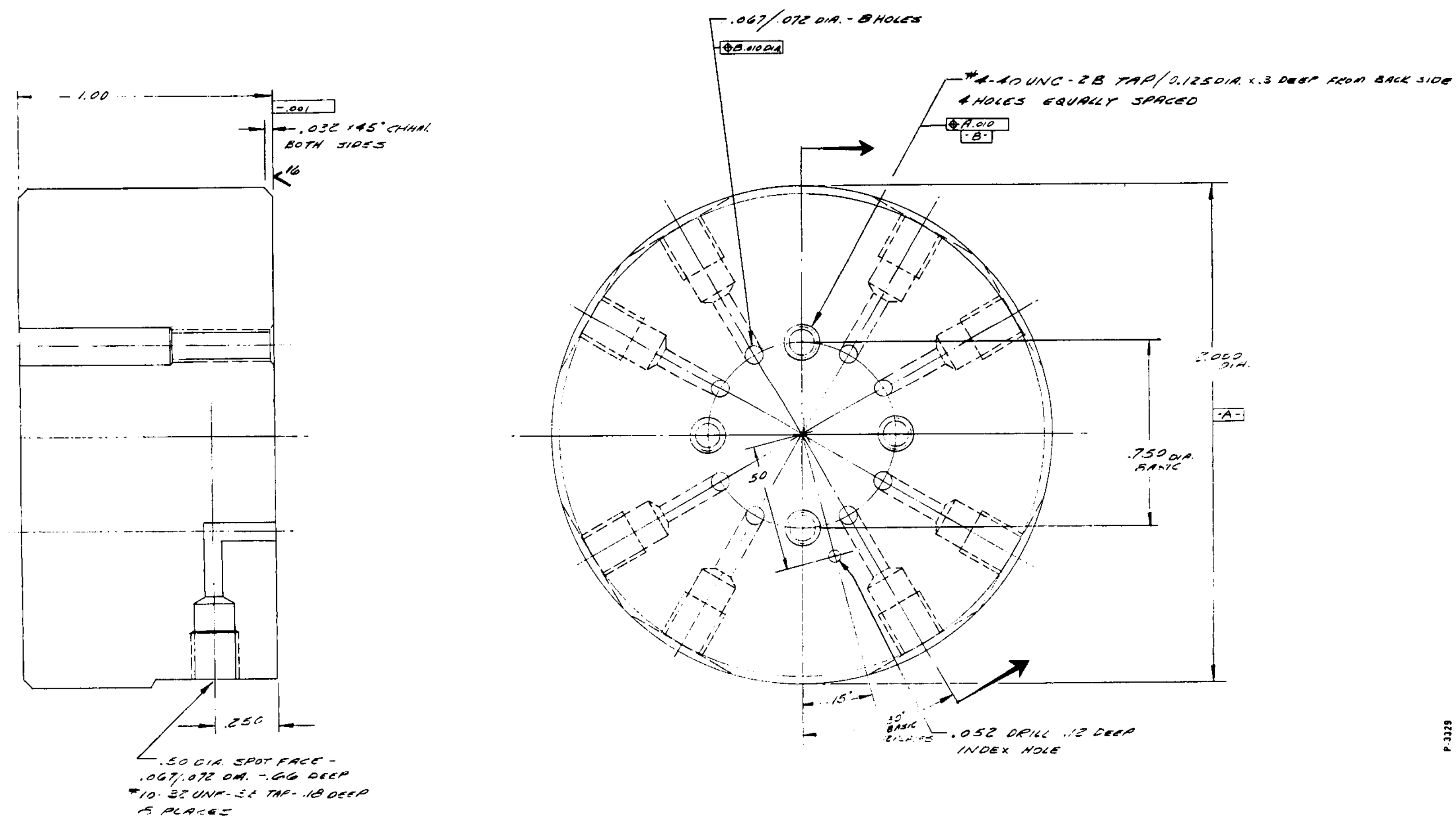


Figure 5-3 - Breadboard Test Fixture

## 5.2 BREADBOARD CIRCUITS

To breadboard the flueric circuits of this system, the individual vortex amplifiers will be mounted on a test fixture. The fixture (see Figure 5-3) communicates the ports of the vortex amplifier to standard tubing fittings. Using these fixtures, the vortex elements can easily be piped into the various circuits or the circuits can be changed as required. (Illustrated in Figure 5-4) The interface between the vortex amplifiers and the fixture is standard, allowing the vortex elements of a circuit to be replaced easily.

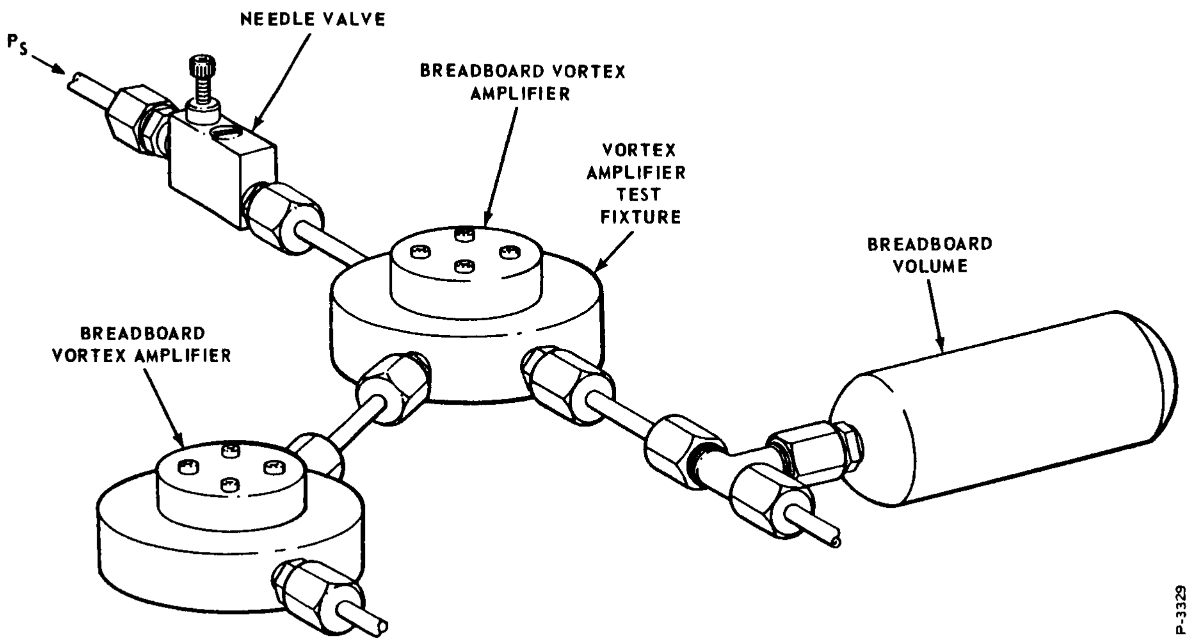


Figure 5-4 - Concept of Breadboarding Flueric Circuit

## SECTION 6

## GOALS OF SECOND QUARTER

The work in this quarter resulted in the simplification of the mechanical design of the flueric circuit and the establishment of a design concept for the breadboard flueric elements and circuit.

The next quarter goals will be to:

(1) Complete design and detail drawings and start with the fabrication of the error detector unit and power control valve.

(2) Design and build the remaining breadboard vortex elements.

(3) Start tests of the flueric circuit.